

10/02/00  
JC912 U.S. PTO

10-03-00

A

DOCKET NO.: CHOI-0038

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In Re Application of:

Xuequan Zhang, et al.

Serial No.: Not yet assigned

Group Art Unit: Not yet assigned

Filing Date: Herewith

Examiner: Not yet assigned

For: **SUPPORTED CATALYST FOR PRODUCING SYNDIOTACTIC  
STYRENIC POLYMER WITH HIGH PRODUCTIVITY AND  
SIGNIFICANTLY REDUCED REACTOR FOULING**

JC882 U.S. PTO  
09/678171  
10/02/00

EXPRESS MAIL LABEL NO: EL531436655US  
DATE OF DEPOSIT: October 2, 2000

Box ☒ Patent Application  
☐ Provisional ☐ Design

Assistant Commissioner for Patents  
Washington DC 20231

Sir:

**PATENT APPLICATION TRANSMITTAL LETTER**

Transmitted herewith for filing, please find

☒ A Utility Patent Application under 37 C.F.R. 1.53(b).

It is a continuing application, as follows:

☐ continuation ☐ divisional ☐ continuation-in-part of prior application number  
\_\_\_\_/\_\_\_\_.

☐ A Provisional Patent Application under 37 C.F.R. 1.53(c).

☐ A Design Patent Application (submitted in duplicate).

Including the following:

- ☐ Provisional Application Cover Sheet.
- ☒ New or Revised Specification, including pages 1 to 33 containing:
- ☒ Specification
  - ☒ Claims
  - ☒ Abstract
  - ☐ Substitute Specification, including Claims and Abstract.
- ☐ The present application is a continuation application of Application No. \_\_\_\_\_ filed \_\_\_\_\_. The present application includes the Specification of the parent application which has been revised in accordance with the amendments filed in the parent application. Since none of those amendments incorporate new matter into the parent application, the present revised Specification also does not include new matter.
- ☐ The present application is a continuation application of Application No. \_\_\_\_\_ filed \_\_\_\_\_, which in turn is a continuation-in-part of Application No. \_\_\_\_\_ filed \_\_\_\_\_. The present application includes the Specification of the parent application which has been revised in accordance with the amendments filed in the parent application. Although the amendments in the parent C-I-P application may have incorporated new matter, since those are the only revisions included in the present application, the present application includes no new matter in relation to the parent application.
- ☐ A copy of earlier application Serial No. \_\_\_\_\_ Filed \_\_\_\_\_, including Specification, Claims and Abstract (pages 1 - @@), to which no new matter has been added TOGETHER WITH a copy of the executed oath or declaration for such earlier application and all drawings and appendices. Such earlier application is hereby incorporated into the present application by reference.
- ☐ Please enter the following amendment to the Specification under the Cross-Reference to Related Applications section (or create such a section) : "This Application:
- ☐ is a continuation of ☐ is a divisional of ☐ claims benefit of U.S. provisional Application Serial No. \_\_\_\_\_ filed \_\_\_\_\_

- 
- 
- 
- ☐ Signed Statement attached deleting inventor(s) named in the prior application.
- ☐ A Preliminary Amendment.
- ☒ 1 Sheets of ☒ Formal ☐ Informal Drawings.
- ☐ Petition to Accept Photographic Drawings.
- ☐ Petition Fee
- ☒ An ☒ Executed ☐ Unexecuted Declaration or Oath and Power of Attorney.
- ☐ An Associate Power of Attorney.
- ☐ An ☐ Executed ☐ Copy of Executed Assignment of the Invention to \_\_\_\_\_  
Samsung General Chemicals Co., Ltd.
- ☐ A Recordation Form Cover Sheet.
- ☐ Recordation Fee - \$40.00.
- ☐ The prior application is assigned of record to \_\_\_\_\_
- ☒ Priority is claimed under 35 U.S.C. § 119 of Patent Application No. 2000- 45602  
\_\_\_\_\_ filed August 7, 2000 in Korea (country).
- ☒ A Certified Copy of each of the above applications for which priority is claimed:
- ☒ is enclosed.
- ☐ has been filed in prior application Serial No. \_\_\_\_\_ filed \_\_\_\_\_.
- ☐ An ☐ Executed or ☐ Copy of Executed Earlier Statement Claiming Small Entity Status under 37 C.F.R. 1.9 and 1.27
- ☐ is enclosed.

☐ has been filed in prior application Serial No. \_\_\_\_\_ filed \_\_\_\_\_, said status is still proper and desired in present case.

- ☐ Diskette Containing DNA/Amino Acid Sequence Information.
- ☐ Statement to Support Submission of DNA/Amino Acid Sequence Information.
- ☐ The computer readable form in this application \_\_\_\_\_, is identical with that filed in Application Serial Number \_\_\_\_\_, filed \_\_\_\_\_. In accordance with 37 CFR 1.821(e), please use the ☐ first-filed, ☐ last-filed or ☐ only computer readable form filed in that application as the computer readable form for the instant application. It is understood that the Patent and Trademark Office will make the necessary change in application number and filing date for the computer readable form that will be used for the instant application. A paper copy of the Sequence Listing is ☐ included in the originally-filed specification of the instant application, ☐ included in a separately filed preliminary amendment for incorporation into the specification.
- ☐ Information Disclosure Statement.
- ☐ Attached Form 1449.
- ☐ Copies of each of the references listed on the attached Form PTO-1449 are enclosed herewith.
- ☐ A copy of Petition for Extension of Time as filed in the prior case.
- ☐ Appended Material as follows: \_\_\_\_\_.
- ☒ Return Receipt Postcard (should be specifically itemized).
- ☐ Other as follows: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_.

## FEE CALCULATION:

- ☐ Cancel in this application original claims \_\_\_\_\_ of the prior application before calculating the filing fee. (At least one original independent claim must be retained for filing purposes.)

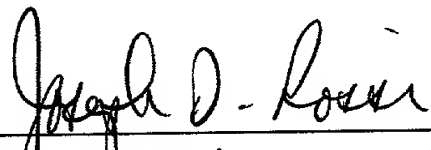
				SMALL ENTITY		NOT SMALL ENTITY	
				RATE	FEE	RATE	FEE
PROVISIONAL APPLICATION				\$75.00	\$	\$150.00	\$
DESIGN APPLICATION				\$160.00	\$	\$320.00	\$
UTILITY APPLICATIONS BASE FEE				\$355.00	\$	\$710.00	\$ 710
UTILITY APPLICATION; ALL CLAIMS CALCULATED AFTER ENTRY OF ALL AMENDMENTS							
		No. Filed	No. Extra				
TOTAL CLAIMS	19	- 20 =	0	\$9 each	\$	\$18 each	\$
INDEP. CLAIMS	4	- 3 =	1	\$40 each	\$	\$80 each	\$ 80
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				\$135	\$	\$270	\$
ADDITIONAL FILING FEE					\$		\$
TOTAL FILING FEE DUE					\$		\$ 790

- ☒ A Check is enclosed in the amount of \$ 790.00.
- ☒ The Commissioner is authorized to charge payment of the following fees and to refund any overpayment associated with this communication or during the pendency of this application to deposit account 23-3050. This sheet is provided in duplicate.
- ☐ The foregoing amount due.
- ☒ Any additional filing fees required, including fees for the presentation of extra claims under 37 C.F.R. 1.16.
- ☒ Any additional patent application processing fees under 37 C.F.R. 1.17 or 1.20(d).
- ☐ The issue fee set in 37 C.F.R. 1.18 at the mailing of the Notice of Allowance.
- ☒ The Commissioner is hereby requested to grant an extension of time for the appropriate length of time, should one be necessary, in connection with this filing or any future filing submitted to the U.S. Patent and Trademark Office in the above-

identified application during the pendency of this application. The Commissioner is further authorized to charge any fees related to any such extension of time to deposit account 23-3050. This sheet is provided in duplicate.

**SHOULD ANY DEFICIENCIES APPEAR** with respect to this application, including deficiencies in payment of fees, missing parts of the application or otherwise, the United States Patent and Trademark Office is respectfully requested to promptly notify the undersigned.

Date: October 2, 2000

  
\_\_\_\_\_  
Joseph D. Rossi  
Registration No. 47,038

Woodcock Washburn Kurtz  
Mackiewicz & Norris LLP  
One Liberty Place - 46th Floor  
Philadelphia PA 19103  
Telephone: (215) 568-3100  
Facsimile: (215) 568-3439

## **Supported Catalyst for Producing Syndiotactic Styrenic Polymer with High Productivity and Significantly Reduced Reactor Fouling**

### **5 Field of the Invention**

The present invention relates to a supported catalyst for producing a styrenic polymer having a syndiotactic configuration. More particularly, the present invention relates to a supported catalyst which is used to prepare a syndiotactic  
10 styrenic polymer with high productivity and with significantly diminished reactor fouling when a stirring-tank reactor is employed.

### **Background of the Invention**

15 Syndiotactic polystyrene (sPS) was first synthesized in 1985, using the homogeneous organometallic catalytic system based on a titanium compound and methylaluminoxane (MAO). Syndiotactic polystyrene is a very attractive polymer. The polymer shows a low specific gravity, a low dielectric constant, a high modulus of elasticity and an excellent resistance to chemicals. Accordingly the  
20 syndiotactic polystyrene has become a promising material for various applications in the automotive, electronic and packaging industries.

A large number of patents on this subject have been filed in recent years. The early patents were dedicated to the synthesis, particularly to the nature of the catalyst and the later patents to the cocatalyst and the other minor components.  
25 Then the problems of the polymerization process were more and more addressed.

In the commercialization of syndiotactic polystyrene, problems, such as serious reactor fouling, and low flow-ability of the product powder resulted from unsatisfactory morphology, remain unsolved if a homogeneous catalyst is used when a stirring-tank reactor is employed. To solve these problems, two alternative  
30 routes seem to be possible: (a) specially designed reactor, and (b) catalyst

supported on insoluble solid. The reactor design is not in the scope of this patent and what to be concerned here is the supported catalyst system.

The activity of a supported metallocene catalyst is, generally, much lower than that of the corresponding homogeneous catalyst by the order of magnitude of 2-3. The polymerization activity of syndiotactic styrene is, generally, much lower than that of polyolefin. Therefore it is very difficult to prepare a supported catalyst having acceptable activity for producing a syndiotactic polystyrene. In order to have the high activity and polymerization efficiency similar to the homogeneous catalyst, the supported catalyst should maintain the basic metallocene structure, and in order to prevent fouling, the catalyst should not be separated from the support during polymerization.

So far, four basic methods have been developed for metallocene catalyst systems for production of polyolefin as follow:

1. direct adsorption of metallocene into the support surface involving physisorption or chemisorption of metallocene (direct heterogenization);
2. initial adsorption of methylaluminoxane (MAO) into the support, followed by adsorption of metallocene (indirect heterogenization);
3. covalent bonding of metallocene to a carrier by a ligand, followed by activation with MAO; and
4. use of an organic compound which is able to react with the hydroxyl group of an inorganic support surface such as silica and to form a complex with metallocene to be supported, which is represented by the following reaction as one example:



where R is a hydrocarbon compound.

Either direct loading of a metallocene catalyst on a support (Method 1) or



indirect loading on a MAO treated support (Method 2) does not provide a good activity for styrenic polymerization. Method 3 relates to a complex chemistry and difficulties arise when bonding the metallocene to the support surface (Soga, Stud Surf .Sci. Cat. 1994, 89, 307). A spacer between support and metallocene was introduced in Method 4, but the results, as reported by Spitz et al. (Macromol. Chem. Phys. 1999, 200, 1453), show that there is no any enhancement of styrene polymerization activity.

Until now, very few reports can be seen in the area of supported catalyst for producing syndiotactic polystyrene. Silica (Kaminsky et al., J. Polym. Sci.: Part A: Polym. Chem. 1999, 37, 2959), alumina (Spitz et al., Macromol. Chem. Phys. 1999, 200, 1453) and polymer (Yu et al., J. Polym. Sci.: Part A: Polym. Chem. 1996, 34, 2237) have been used as a support for preparation of a supported catalyst for producing syndiotactic polystyrene. Unfortunately, all these supported catalysts are not applicable because of extremely low activity. Therefore, a supported catalyst with high activity for producing syndiotactic styrenic polymer is highly expected. The present inventors have developed a supported catalyst with high activity, which is used to prepare a syndiotactic styrenic polymer with high productivity and with significantly diminished reactor fouling when a stirring-tank reactor is employed.

## **20    Objects of the Invention**

A feature of the present invention is the provision of a supported catalyst with high activity for preparing syndiotactic styrenic polymer.

Another feature of the present invention is the provision of a supported catalyst with high activity for preparing syndiotactic styrenic polymer with high productivity.

A further feature of the present invention is the provision of a supported catalyst with high activity for preparing syndiotactic styrenic polymer, which can significantly diminish reactor fouling when a stirring-tank reactor is employed.

A further feature of the present invention is the provision of syndiotactic styrenic polymer powder with good flowability and morphology.

The above and other objects and advantages of this invention will be apparent from the ensuing disclosure and appended claims.

### Summary of the Invention

5

The supported catalyst according to the present invention comprises (A) a support of organic or inorganic powder with a high-surface area, (B) a polymer coated onto the support and (C) a homogeneous transition metal compound as essential component, the polymer (B) functioning an insulation layer between the support and the metal compound. The supported catalyst can contain optionally (D) alkyl aluminoxane and/or (E) alkyl aluminum compound. By using the supported catalyst provided by the present invention, the productivity of styrenic polymer is much increased and the reactor fouling was significantly reduced. The supported catalyst can be used in combination with a cocatalyst, preferably an alkyl aluminoxane. The styrenic polymer powder such produced by the present invention has good flow-ability and good morphology demonstrating a great deal of industrial applicability.

### Brief Description of the Drawings

20

Fig. 1 is a schematic drawing illustrating insulation concept of the supported catalyst according to the present invention by the insulation layer of polymer between the support and the metallocene; and

Fig. 2 is a schematic process for preparing a supported catalyst according to the present invention.

### Detailed Description of the Invention

It is believed that the key point to obtain a high activity metallocene

supported catalyst is to keep the metallocene catalyst to be supported from the poisonous surface of the support without deterioration of the advantages of the supported catalyst.

In Method 4 above, an organic compound reacts with hydroxyl groups, or Si-OH groups in case of silica, of the surface of a support and can form a reactive complex with metallocene. However, the method is not effective because, even though the hydroxyl groups of the support are capped, the non-hydroxyl group area of the surface of the support (-Si-O-Si-, in case of silica) still remains bare, and the bare acidic surface is poisonous to the catalyst.

With this thought in mind, the present inventors have used a polymer to completely insulate the homogeneous catalyst to be supported from the poisonous surface of the support, thereby functioning an insulation layer between the catalyst and the support. To constitute an insulation layer, the polymer should be harmless to catalyization performances, have chemical or physical interaction with the catalyst and support, and be insoluble in the styrenic monomer or polymerization solvent after the catalyst is loaded. Fig. 1 is a schematic drawing illustrating insulation concept of the supported catalyst according to the present invention by the insulation layer of polymer between the support and the metallocene.

The polymers to meet the requirements described above are those containing particular polar groups. The particular polar groups of the polymer interact chemically or physically with the surface of a support. Accordingly the polymer can be completely absorbed on the surface of the support to form an insulation film, somewhat like a coating process.

While the insulation layer is formed, the polar groups absorb metallocene catalyst to be supported by formation of a stable complex, and act as a media or a substitute for support to load the homogeneous catalyst. With the insulation layer on the surface of the support, the intrinsic characteristic of the support become not so important as it used to be and the support itself only provides the morphology and high surface area of the supported catalyst. This may lead to the following significant changes on the level of basic concept of the support catalyst:

(1) The treatment of an inorganic support can be conducted more easily at more mild conditions because the chemical properties of the support surface are sheltered by the insulation layer, and

(2) An organic polymer powder such as a neucent polyolefin powder, which possesses high surface area and good morphology but is not able to load metallocene catalyst because of the non-polar nature, can be used as a catalyst support. Because the insulation layer on the support surface can load the metallocene catalyst.

As shown in Fig. 1, a polymer is used to form an insulation layer 2 on the surface of a support 1. Representative polymers suitable for this purpose include acrylonitrile-containing polymers and copolymers, hydroxyl group-containing polymer and copolymers, acrylic and acrylate polymers and copolymers, maleic anhydride-containing copolymers and maleic anhydride modified polymers, acetate containing polymers and copolymers, polyethers, polyketones, polyamide polymer and copolymers, and polyurethanes.

Specific examples of the acrylonitrile-containing polymers and copolymers are polyacrylonitrile, poly(acrylonitrile-block-styrene), poly(styrene-co-acrylonitrile), acrylonitrile-butadiene-styrene resin, poly(acrylonitrile-co-butadiene), poly(acrylonitrile-co-isoprene), etc. The acrylonitrile content in the copolymers is not specifically limited, but is usually about from 0.1 to 100 % by weight, preferably about from 2 to 50 % by weight. Specific examples of hydroxyl group-containing polymer and copolymers are poly(vinyl alcohol), and hydroxyl group functionalized polymers and copolymers.

The amount of polymer 2 for the insulation layer is not limited, but is preferably in the range of about 0.0001 to 99.999 % by weight as per the supported catalyst.

The support 1 used for preparation of the supported catalyst according to the present invention includes both inorganic supports and organic supports.

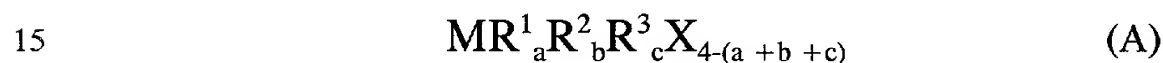
The representative examples of the inorganic supports include silica gel, alumina, silica-alumina gel, zeolite, mica powder, clays, molecular sieves, metal

oxide compounds, metal halogenides, metal carbonates and metal powder. Silica gel, silica-alumina gel and alumina are most preferable among the inorganic solids.

The representative examples of the organic supports include poly(styrene-co-divinylbenzene) beads, starch powder and polyolefin powder. The polyolefin powder includes polyethylene powder, polypropylene powder, olefin copolymer powder, etc.

The amount of support 1 is not limited, but is preferably in the range of about 0.0001 to 99.999 % by weight as per the supported catalyst. Preferably the support is used over 70 % by weight as per the supported catalyst.

The transition metal compound used as a homogeneous catalyst in the present invention is a Group IVB metal compound represented by the following formula (A) or (B):



where M is an atom of Group IVB,  $\text{R}^1$ ,  $\text{R}^2$  and  $\text{R}^3$  are a hydrogen atom, an alkyl group having 1 to 20 carbon atoms, an alkoxy group having 1 to 20 carbon atoms, an aryl group having 6 to 20 carbon atoms, an alkylaryl group having 6 to 20 carbon atoms, an arylalkyl group having 6 to 20 carbon atoms, an aryloxy group having 1 to 20 carbon atoms, a cyclopentadienyl group, a substituted cyclopentadienyl group or an indenyl group, X is a halogen atom, a, b and c are an integer of 0 to 4, and d and e are an integer of 0 to 3.

Representative examples of the alkyl group having 1 to 20 carbon atoms as represented by  $\text{R}^1$ ,  $\text{R}^2$  or  $\text{R}^3$  are a methyl, an ethyl, a propyl, a butyl, an amyl, an isoamyl, an isobutyl, an octyl and a 2-ethylhexyl.

Representative examples of the alkoxy group having 1 to 20 carbon atoms are

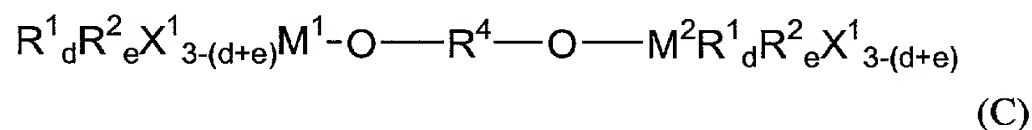
a methoxy, an ethoxy, a propoxy, a butoxy, an amyloxy, a hexyloxy and a 2-ethylhexyloxy.

Representative example of the aryl, alkylaryl or arylalkyl having 6 to 20 carbon atoms are a phenyl, a tolyl, a xylyl and a benzyl.

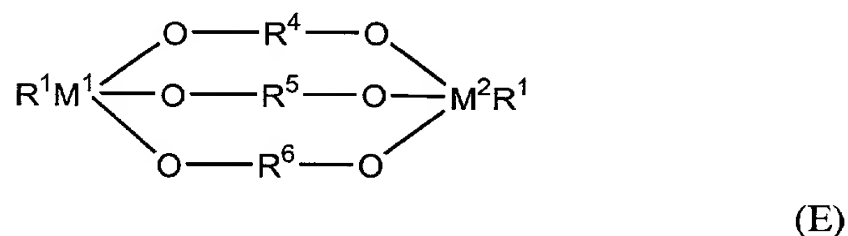
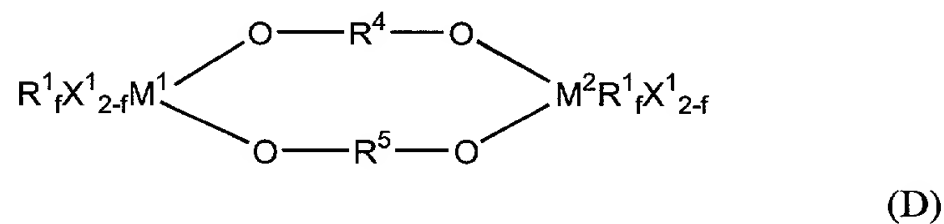
5 In the general formulae (A) and (B),  $R^1$ ,  $R^2$  and  $R^3$  may be the same or different one another.

The transition metal component used for preparation of the supported catalyst according to the present invention further includes, besides single nuclear catalysts as represented in formula (A) or (B), binuclear and multiple-nuclear catalysts as  
10 well.

The binuclear catalyst is represented by the following formula (C), (D) or (E):



15



20 where  $M^1$  and  $M^2$  are an atom of Group IVB,  $R^1$ ,  $R^2$ ,  $R^4$ ,  $R^5$  and  $R^6$  are an alkyl group having 1 to 20 carbon atoms, an aryl group having 6 to 20 carbon atoms, an alkylaryl group having 6 to 20 carbon atoms, an arylalkyl group having 6 to 20

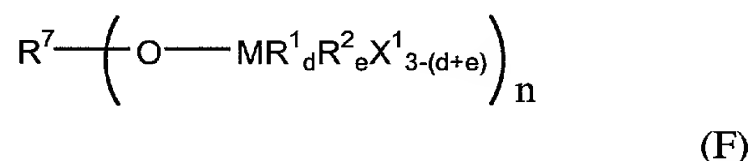
carbon atoms, a cyclopentadienyl group, a substituted cyclopentadienyl group or an indenyl group, X is a halogen atom, d and e are an integer of 0 to 3, and f is an integer of 0 to 2.

5 Representative examples of the alkyl group having 1 to 20 carbon atoms as represented by  $R^4$ ,  $R^5$  or  $R^6$  are a methyl, an ethyl, a propyl, a butyl, an amyl, an isoamyl, an isobutyl, an octyl and a 2-ethylhexyl.

Representative example of the aryl, alkylaryl or arylalkyl having 6 to 20 carbon atoms are a phenyl, a tolyl, a xylyl and a benzyl.

10 In the general formulae (C), (D) and (E),  $R^4$ ,  $R^5$  and  $R^6$  may be identical or different one another.

The multiple-nuclear catalyst is represented by the formula (F):



15 where M is an atom of Group IVB,  $R^1$  and  $R^2$  are an alkyl group having 1 to 20 carbon atoms, an aryl group having 6 to 20 carbon atoms, an alkylaryl group having 6 to 20 carbon atoms, an arylalkyl group having 6 to 20 carbon atoms, a cyclopentadienyl group, a substituted cyclopentadienyl group or an indenyl group,  $R^7$  is an alkyl group having 1 to 20 carbon atoms, an aryl group having 6 to 20 carbon atoms, an alkylaryl group having 6 to 20 carbon atoms, an arylalkyl group having 6 to 20 carbon atoms, or a polymer having a polymerization degree of 5 to 10000, X is a halogen atom, d and e are an integer of 0 to 3, and n is an integer of 3 to 1000.

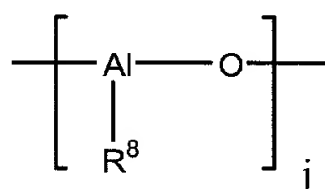
25 The transition metal compound 3 may be used alone or in combination of two or more types. The amount of the transition metal compound 3 is not limited, but is preferably in the range of about 0.0001 to 30.0 % by weight as per the supported

catalyst.

The supported catalyst can contain optionally (D) alkyl aluminoxane and/or (E) alkyl aluminum compound.

In the preparation process of the supported catalyst according to the present invention, an alkyl aluminoxane compound is used, where necessary, as a component (D).

The alkyl aluminoxane compound is a product of the reaction of an alkyl aluminum and a condensation reagent such as water. The alkyl aluminoxane compound is represented by the following general formula (G):



(G)

where  $\text{R}^8$  is an alkyl group having 1 to 8 carbon atoms, and  $j$  is a number of 2 to 50.

The chain structure of the component (D), alkyl aluminoxane, represented by general formula (G) is linear or cyclic.

The amount of the component (D) is not limited, but is preferably in the range of about 0 to 50 % by weight as per the supported catalyst.

In the preparation process of the supported catalyst in the present invention, an alkyl aluminum compound represented by the general formula (H) is used when necessary, as a component (E).



where  $\text{R}^9$  is an alkyl group having 1 to 8 carbon atoms.

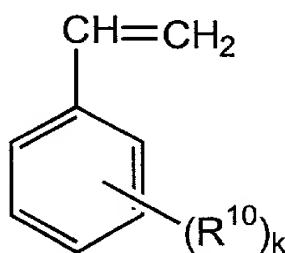


The amount of the component (E) is not limited, but is preferably in the range of about 0 to 50 % by weight as per the supported catalyst.

Among the components, which are described as above, for preparation of the supported catalyst according to the present invention, components (A), (B) and (C) are essential, and components (D) and (E) can be used together or individually in combination with components (A), (B) and (C) when they are necessary. Fig. 2 is a schematic process for preparing a supported catalyst according to the present invention. The reaction procedures and the addition sequences of these components for preparation of supported catalyst are not specifically limited, but those as shown in Fig. 2 are preferred.

The solvent used for preparation of the supported catalyst is not specifically limited, but aliphatic and aromatic hydrocarbon solvents are preferred, which is easily conducted by an ordinary skilled person in the art to which the present invention pertains. The reaction temperature for preparation of the supported catalyst is usually about from  $-100^{\circ}\text{C}$  to  $150^{\circ}\text{C}$ , preferably from  $20$  to  $70^{\circ}\text{C}$ .

The styrenic monomer is polymerized to prepare syndiotactic styrenic polymer by using the supported catalyst provided by the present invention. The styrenic monomer is represented by the formula (I):

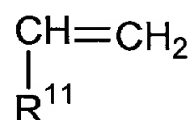


(I)

where each  $\text{R}^{10}$  is individually selected from the group consisting of a hydrogen atom, a halogen atom and a substituent group which contains a carbon atom, an oxygen atom, a nitrogen atom, a sulfur atom, a phosphorus atom or a silicon atom, and  $k$  represents an integer of 1 to 3.

The styrenic monomer can be not only homopolymerized, but also copolymerized when two or more styrenic monomers are used, by using the supported catalyst provided by the present invention.

5        The monomers which can be polymerized by the supported catalyst according to the present invention are not limited to the styrenic monomers. Olefin monomers represented by the general formula (J) can also be polymerized alone and copolymerized with a monomer. The copolymerization can be carried out between olefin monomers or between an olefin monomer and a styrenic monomer.



10

(J)

where  $\text{R}^{11}$  is a hydrogen atom, or a linear or cyclic alkyl group having 1 to 20 carbon atoms.

15        The supported catalyst provided by the present invention is preferably used in combination with a cocatalyst for producing syndiotactic styrenic polymer. Alkyl aluminoxane (D) and/or alkyl aluminum compound (E) can be used as cocatalysts.

20        By using the supported catalyst provided by the present invention, the productivity of styrenic polymer is much increased and the reactor fouling was significantly reduced. The styrenic polymer powder such produced by the present invention has good flow-ability and good morphology demonstrating a great deal of industrial applicability.

25        The present invention will be described in more detail by the following Examples. The Examples are given only to illustrate the present invention and not intended in any way to limit the scope of the invention.

**Examples 1-4.****Preparation of HDPE-Catalyst Support**

To a dried 250ml flask equipped with a magnetic stirring bar, 10g of high-density polyethylene (HDPE) powder (product by Samsung General Chemical co. Ltd. of Korea; powder size: 80~150 mesh, melt index: 0.045g/10min), 0.5g of SAN (styrene-acrylonitrile copolymer) (product by Cheil Industries Inc. of Korea; acrylonitrile content: 23wt%, Mw: 90000) and 80ml of toluene were added under a nitrogen atmosphere. The resulting slurry was allowed to stir at room temperature for 2 hours for completely dissolution of the SAN polymer, and then toluene was removed by decantation followed by vacuum. Thus, a white well-flow powder product was obtained. To the white powder, 2mmol of methyl aluminoxane (MAO) in 80ml toluene was added at room temperature. The slurry was kept at room temperature with stirring for 30 minutes, and then toluene was removed by decantation followed by vacuum. As a result, a white finely divided solid was obtained as an HDPE-catalyst support. The aluminum content was measured to be 1.33wt% (0.05mmol/g) by ICP analysis.

**Polymerization by Using HDPE-Catalyst Support**

0.5g of HDPE-catalyst support was weighed into a 25ml vial in a dry box, then 0.02mmol of pentamethyl cyclopentadienyl titanium trimethoxide ( $\text{Cp}^*\text{Ti}(\text{OCH}_3)_3$ ) in 15ml toluene solution was added by syringe. The slurry was kept at room temperature for 1 hour.

To a dried 1L-glass reactor equipped with a circulation water jacket for temperature control and an anchor-paddle impeller (made of steel), 200ml of purified styrene monomer and 3ml of triisobutyl aluminum (60mmol/L-SM) were added. The solution was stirred at 70°C and 400 rpm for 10 minutes, and then 0.71ml of 2.83M methyl aluminoxane (2 mmol) toluene solution and the catalyst slurry prepared above were injected. Polymerization proceeded for 1 hour, then the resulting solution was quenched by a large amount of methanol. The polymer was

filtered and dried by vacuum at 150°C. As a result, 114.8g of powder polymer was obtained. The conversion was 63.7%, the activity was 5.74kg/mmol-Ti-hr and the reactor fouling was 2.32wt%.

The polymer obtained was analyzed by  $^{13}\text{C}$  NMR and DSC to be a highly syndiotactic polystyrene with the melting point of 270°C. The weight-average molecular weight (Mw) and molecular weight distribution (Mw/Mn) were determined by GPC to be 561,000 and 1.95, respectively.

Examples 2-4 were carried out in the same manner as Example 1 except that triisobutyl aluminum was used at 40, 60 and 80 mmol/L in Examples 2, 3 and 4, respectively. The resulting data were shown in Tables 1 and 2.

### Examples 5-8

#### Preparation of sPS-Catalyst Support

To a dried 250ml flask equipped with a magnetic stirring bar, 10g of syndiotactic polystyrene (sPS) powder (Laboratory-made, powder size: 20 ~ 150 mesh, Mw: 1,280,000, Mw/Mn = 2.95), 0.5g of SAN (poly(styrene-co-acrylonitrile)) (product by Samsung Cheil Industries Inc., acrylonitrile content: 23wt%, Mw: 90000) and 80ml of toluene were added under a nitrogen atmosphere. The resulting slurry was allowed to stir at room temperature for 2 hours for completely dissolution of the SAN polymer, and then toluene was removed by decantation followed by vacuum. Thus, a white well-flow powder was obtained. To the white powder, 2mmol of methylaluminoxane (MAO) in 80ml toluene was added at room temperature. The slurry was kept at room temperature with stirring for 30 minutes, and then toluene was removed by decantation followed by vacuum. As a result, a white finely divided solid was obtained as an sPS-catalyst support.

#### Polymerization by Using sPS-Catalyst Support

0.5g of sPS-catalyst support was weighed into a 25ml vial in a dry box, then 0.02mmol of pentamethyl cyclopentadienyl titanium trimethoxide ( $\text{Cp}^*\text{Ti}(\text{OCH}_3)_3$ )

in 15ml toluene solution was added by syringe. The slurry was kept at room temperature for 1 hour.

To a dried 1L-glass reactor equipped with a circulation water jacket for temperature control and an anchor-paddle impeller (made of steel), 200ml of purified styrene monomer and 3ml of triisobutyl aluminum (60mmol/L-SM) were added. The solution was stirred at 70°C and 400 rpm for 10 minutes, and then 0.71ml of 2.83M methyl aluminoxane (2 mmol) toluene solution and the catalyst slurry prepared above were injected. Polymerization proceeded for 1 hour, then the resulting solution was quenched by a large amount of methanol. The polymer was filtered and dried by vacuum at 150°C. As a result, 108.4g of powder polymer was obtained. The conversion was 59.6%, the activity was 5.42/mmol-Ti-hr and the reactor fouling was 0.46wt%.

The polymer obtained was analyzed by  $^{13}\text{C}$  NMR and DSC to be a highly syndiotactic polystyrene with the melting point of 270°C. The weight-average molecular weight (Mw) and molecular weight distribution (Mw/Mn) were determined by GPC to be 607,000 and 2.45, respectively.

Examples 6-8 were carried out in the same manner as Example 5 except that isobutyl aluminum was used at 40, 60 and 80 mmol/L in Examples 6, 7 and 8, respectively. The resulting data were shown in Tables 1 and 2.

#### Comparative Examples 1-4

To a dried 1L-glass reactor, equipped with a circulation water jacket for temperature control and an anchor-paddle impeller (made of steel), 200ml of purified styrene monomer and 1ml of triisobutyl aluminum (20mmol/L-SM) were added. The solution was stirred at 70°C and 400 rpm for 10 minutes, and then 0.71ml of 2.83M methyl aluminoxane (2 mmol) toluene solution and 0.02mmol of homogeneous catalyst, pentamethyl cyclopentadienyl titanium trimethoxide ( $\text{Cp}^*\text{Ti}(\text{OCH}_3)_3$ ) in 15ml toluene solution were injected. The system became highly viscous and finally became a lump about 2 ~ 3 minutes after polymerization

started. The polymerization could not proceed because the system could not be agitated. The polymerization was stopped by quenching with methanol.

Comparative Examples 2-4 were carried out in the same manner as Comparative Example 1 except that triisobutyl aluminum was used at 40, 60 and 80 mmol/L in Comparative Examples 2, 3 and 4, respectively. The similar lump polymer were obtained by using the homogeneous catalyst,  $\text{Cp}^*\text{Ti}(\text{OCH}_3)_3$  in Comparative Example 2-4.

The polymerization conditions and resulting data were listed in Table 1.

#### 10 Comparative Example 5

*Prepolymerization:* To a dried 1L-glass reactor equipped with a circulation water jacket for temperature control and an anchor-paddle impeller (made of steel), 200ml of purified styrene monomer and 8ml of triisobutyl aluminum (32mmol) were added. The solution was stirred at 70 °C and 400 rpm for 10 minutes, and then 0.25ml of 2.83M methyl aluminoxane (0.72 mmol) toluene solution and 0.0072mmol of homogeneous catalyst,  $\text{Cp}^*\text{Ti}(\text{OCH}_3)_3$ , in 2ml toluene solution were injected. The prepolymerization proceeded for 1 hour.

*Polymerization:* The polymerization started with injection of 0.16ml of 2.83M methyl aluminoxane (0.47mmol) and 0.0047mmol of homogeneous catalyst,  $\text{Cp}^*\text{Ti}(\text{OCH}_3)_3$ . 0.47mmol of MAO and 0.0047mmol of  $\text{Cp}^*\text{Ti}(\text{OCH}_3)_3$  were repeatedly injected 7 times at interval of 5 minutes until the total amount of 4mmol MAO and 0.04mmol of  $\text{Cp}^*\text{Ti}(\text{OCH}_3)_3$  (including MAO and catalyst in prepolymerization) were reached. The catalyst and MAO injection time was 30 minutes and the polymerization was allowed to proceed for another 30 minutes. The polymerization was terminated with addition of a large amount of methanol. Finally, fine polymer was obtained together with serious reactor and impeller fouling. The total yield was 121.8g, conversion was 67.0%, reactor fouling was 25% and the activity was 1.52kg/mmol-Ti-hr. The polymerization conditions and

resulting data were listed in Tables 1 and 2.

Table 1

	catalyst support	[Cat] mmol/L	[TiBA] mmol/L	Polym. Time Min	Yield %	Fouling %	Activity kg/mmol-Ti-h
Example 2	HDPE	0.1	20	60	47.4	1.28	4.3
Example 3	HDPE	0.1	40	60	58.3	1.30	5.3
Example 4	HDPE	0.1	60	60	63.7	2.32	5.8
Example 5	HDPE	0.1	80	60	54.3	0.80	4.9
Example 7	sPS	0.1	20	60	35.0	2.15	3.2
Example 8	sPS	0.1	40	60	38.0	2.17	3.5
Example 9	sPS	0.1	60	60	59.6	0.46	5.4
Example 10	sPS	0.1	80	60	48.3	1.02	4.4
Comparative Example 1	None	0.1	20	3	-	Lump	-
Comparative Example 2	None	0.1	40	3	-	Lump	-
Comparative Example 3	None	0.1	60	3	-	Lump	-
Comparative Example 4	None	0.1	80	3	-	Lump	-
Comparative Example 5	None	0.2	160	120	67.0	25.0	1.5

- 5 Polymerization conditions: SM: 200ml, [MAO]/[Ti] = 100,  
Polymerization temperature: 70°C; rpm: 400/min.

Table 2

	catalyst support	[Cat] mmol/L	[TiBA] mmol/L	Polym. Time Min	Mw ×10 <sup>-3</sup>	Mw/Mn
Example 2	HDPE	0.1	20	60	852	1.88
Example 3	HDPE	0.1	40	60	666	2.21
Example 4	HDPE	0.1	60	60	561	1.95
Example 5	HDPE	0.1	80	60	424	1.93
Example 7	sPS	0.1	20	60	816	1.98
Example 8	sPS	0.1	40	60	762	1.90
Example 9	sPS	0.1	60	60	607	2.45
Example 10	sPS	0.1	80	60	604	2.09
Comparative Example 5	None	0.2	160	120	358	1.75

Polymerization conditions: SM: 200ml, [MAO]/[Ti] = 100,

Polymerization temperature: 70°C ; rpm: 400/min.

As shown in Table 1, powder polymers were obtained with the reactor fouling below 3 wt% when either an HDPE-catalyst support (Examples 2 ~ 5) or an sPS-catalyst support (Examples 7 ~ 10) was used. In contrast, despondent lump polymer was yielded when only a homogeneous catalyst ( $\text{Cp}^*\text{Ti}(\text{OCH}_3)_3$ ) was used in Comparative Examples 1 ~ 4. The powder polymer was yielded by using only homogeneous catalyst ( $\text{Cp}^*\text{Ti}(\text{OCH}_3)_3$ ) in Comparative Example 5 where pre-polymerization was employed, and feeding speed of catalyst and cocatalyst was controlled. As the results of Comparative Example 5, the productivity of sPS was much decreased together with tremendous reactor fouling (25 wt%).

The narrow molecular weight distribution showed in Table 2 indicated that even though the catalyst supports were used, the single-sited characteristic of the catalyst was not changed. Additionally, the molecular weight of the sPS polymer was in a good range and also it could be controlled by the concentration of triisobutyl aluminum (TiBA).

### **Example 9 : Polymerization in 10L Stirring Tank Reactor Using sPS-Catalyst Support**

5g of sPS-catalyst support was weighed into a 100ml vial in a dry box, then 0.06mmol of  $\text{Cp}^*\text{Ti}(\text{OCH}_3)_3$  in 15ml toluene solution was added by syringe. The slurry was kept at room temperature for 1 hour.

A 10L Bench reactor was purged with nitrogen at 100°C for 2 hours, and then it was cooled to 80°C. 2000ml of purified styrene monomer and 40mmol of triisobutyl aluminum (TiBA) in toluene solution were transferred to the reactor by nitrogen pressure. The reactor was allowed to stir at 300 rpm at 80°C under nitrogen atmosphere for 10 minutes. 2.12ml of 2.83M of MAO (6mmol) in toluene solution and the catalyst slurry prepared above were injected simultaneously. The polymerization was allowed to proceed for 40 minutes, and then the polymer powder was discharged out through the bottom drain of the reactor.



The polymer powder was collected and dried by vacuum. As the results, 781.7g of sPS powder was obtained. The conversion was 43.1 % and activity was 19.2kg/mmol-Ti-hr. The reaction conditions and resulting data are shown in Table 3.

5

### Comparative Example 6

A 10L Bench reactor was purged with nitrogen at 100°C for 2 hours, and then it was cooled to 80°C. 2000ml of purified styrene monomer and 40mmol of triisobutyl aluminum (TiBA) in toluene solution were transferred to the reactor by nitrogen pressure. The reactor was allowed to stir at 300 rpm at 80°C under nitrogen atmosphere for 10 minutes. 2.12ml of 2.83M of MAO (6mmol) in toluene solution and 0.06mmol of Cp\*Ti(OCH<sub>3</sub>)<sub>3</sub> in 15ml toluene solution were injected simultaneously. About 10 minutes after polymerization started, polymerization could not proceed because of high stirrer ampere. The reactor was opened. Completely lump-like polymer was obtained and no powder-like sPS was yielded. The reaction conditions and resulting data are shown in Table 3.

10

15

### Comparative Example 7

20

*Prepolymerization:* A 10L Bench reactor was purged with nitrogen at 100°C for 2 hours, and then it was cooled to 80°C. 2000ml of purified styrene monomer and 40mmol of triisobutyl aluminum (TiBA) in toluene solution were transferred to the reactor by nitrogen pressure. The reactor was allowed to stir at 300 rpm at 70°C under nitrogen atmosphere for 10 minutes, and then 0.83ml of 2.83M methyl aluminoxane (2.4 mmol) toluene solution and 0.024mmol of homogeneous catalyst, Cp\*Ti(OCH<sub>3</sub>)<sub>3</sub>, in 2ml toluene solution were injected. The prepolymerization was proceeded for 1 hour.

25

*Polymerization:* The polymerization started with injection of 0.54ml of 2.83M methyl aluminoxane (1.5mmol) and 0.015mmol of homogeneous catalyst,

30

Cp\*Ti(OCH<sub>3</sub>)<sub>3</sub>. The 1.5 mmol of MAO and 0.015mmol of Cp\*Ti(OCH<sub>3</sub>)<sub>3</sub> were repeatedly injected 7 times at time interval of 5 minutes until total amount of 13.2mmol MAO and 0.132mmol of Cp\*Ti(OCH<sub>3</sub>)<sub>3</sub> (including MAO and catalyst in prepolymerization) were reached. The catalyst and MAO injection time was 30 minutes and the polymerization was allowed to proceed for another 1 hour. Finally, fine polymer powder was obtained together with serious reactor and impeller fouling. The total yield was 1182g, conversion was 65.0%, reactor fouling was 25% and the activity was 3.58kg/mmol-Ti-hr. The polymerization conditions and resulting data are shown in Table 3.

Table 3

	Catalyst support	[Cat] mmol/L	[TiBA] mmol/L	Polym. time min	Yield %	Activity kg/mmol-Ti-h
Example 9	SPS	0.030	20	40	43.1	19.2
Comparative Example 6	None	0.030	20	10	-	lump
Comparative Example 7	None	0.066	50	150	65.0	3.58

Polymerization conditions: SM: 2000ml, [MAO]/[Ti] = 100, Polymerization temperature: 80 °C; rpm: 400/min.;

The productivity using sPS-catalyst support in Example 11 was significantly higher than that of only using the homogeneous catalyst where the method of prepolymerization and controlled feeding speed of catalyst had to be employed in Comparative Example 7.

### Examples 10~12

#### Preparation of Silica-Catalyst Support

To a dried 250ml flask equipped with a magnetic stirring bar, 10g of silica (Davison Chemical co., dried at 600°C for 6 hours before use), 0.5g of SAN (styrene-acrylonitrile copolymer) (product by Samsung Cheil Industries Inc. of

Korea, acrylonitrile content: 23wt%, Mw: 90000) and 80ml of toluene were added under nitrogen atmosphere. The resultant slurry was allowed to stir at room temperature for 2 hours for complete dissolution of the SAN polymer, and then toluene was removed by decantation followed by vacuum. Thus, white well-flow powder was obtained. To the white powder, 2mmol methyl aluminoxane (MAO) in 80ml toluene was added at room temperature. The slurry was kept at room temperature with stirring for 30 minutes, and then toluene was removed by decantation followed by vacuum. As a result, a white finely divided solid was obtained as a silica-catalyst support.

In Examples 10, 11 and 12, the silica was calcinated at 600 °C, 200°C and 400°C, respectively.

#### **Polymerization by using Silica-Catalyst Support**

0.9g of silica-catalyst support of Example 10 was weighed into a 25ml vial in a dry box, then 0.04mmol of  $\text{Cp}^*\text{Ti}(\text{OCH}_3)_3$  in 15ml toluene solution was added by syringe. The slurry was kept at the room temperature for 1 hour.

To a dried 1L-glass reactor equipped with a circulation water jacket for temperature control and an anchor-paddle impeller (made of steel), 200ml of purified styrene monomer and 4ml of triisobutyl aluminum (80mmol/L-SM) were added. The solution was stirred at 70 °C and 400 rpm for 10 minutes, and then 1.41ml of 2.83M methyl aluminoxane (4 mmol) toluene solution and the catalyst slurry prepared above were injected. Polymerization proceeded for 2 hour, then was quenched by a large amount of methanol. The polymer was filtered and dried by vacuum at 150 °C. As a result, 122.4g of powder polymer was obtained. The conversion was 67.3%, the activity was 1.53kg/mmol-Ti-hr and the reactor fouling was 2.8wt%.

The polymer obtained was analyzed by  $^{13}\text{C}$  NMR and DSC to be a highly syndiotactic polystyrene with the melting point of 270 °C. The weight-average molecular weight (Mw) and molecular weight distribution (Mw/Mn) were determined by GPC to be 353,100 and 3.16, respectively.

The polymerization procedures were repeated for the silica-catalyst supports of Examples 11 and 12. The polymerization data are shown in Tables 4 and 5.

#### **Examples 13~16 : Polymerization by Using Silica-Catalyst Support**

5        0.2g silica-catalyst support of Example 10 was weighed into a 25ml vial in a dry box, then 0.04mmol of  $\text{Cp}^*\text{Ti}(\text{OCH}_3)_3$  in 15ml of toluene solution was added by syringe. The slurry was kept at room temperature for 1 hour.

10        To a dried 1L-glass reactor equipped with a circulation water jacket for temperature control and an anchor-paddle impeller (made of steel), 200ml of purified styrene monomer and 2ml of triisobutyl aluminum (40mmol/L-SM) were added. The solution was stirred at 70 °C and 400 rpm for 10 minutes, and then 1.41ml of 2.83M methyl aluminoxane (4 mmol) toluene solution and the catalyst slurry prepared above were injected. Polymerization proceeded for 1 hour, then was quenched by a large amount of methanol. The polymer was filtered and dried  
15 by vacuum at 150 °C. As a result, 104.9g of powder polymer was obtained. The conversion was 57.7%, the activity was 2.62kg/mmol-Ti-hr and the reactor fouling was 1.4wt%.

20        The polymer obtained was analyzed by  $^{13}\text{C}$  NMR and DSC to be a highly syndiotactic polystyrene with the melting point of 270 °C. The weight-average molecular weight (Mw) and molecular weight distribution (Mw/Mn) were determined by GPC to be 493,100 and 1.90, respectively.

25        Examples 14-16 were carried out in the same manner as Example 13 except that triisobutyl aluminum was used at 40, 60 and 80 mmol/L in Examples 14, 15 and 16, respectively. The resulting data were shown in Tables 4 and 5.

#### **Comparative Example 8**

30        The same polymerization procedures as in Example 13 ~ 16 were repeated except that silica-supported methyl aluminoxane (sMAO) and homogeneous catalyst,

$\text{Cp}^*\text{Ti}(\text{OCH}_3)_3$ , were used in stead of MAO in toluene solution and silica-supported catalysts, respectively.

To a dried 1L-glass reactor equipped with a circulation water jacket for temperature control and an anchor-paddle impeller (made of steel), 200ml of purified styrene monomer and 3ml of triisobutyl aluminum (60mmol/L-SM) were added. The solution was stirred at 70 °C and 400 rpm for 10 minutes, and then 0.73g sMAO (4 mmol), produced by Akzo Nobel, Al content: 14.8wt%, in toluene slurry and 0.04mmol of  $\text{Cp}^*\text{Ti}(\text{OCH}_3)_3$  in 10 ml toluene solution were injected. Polymerization proceeded for 2 hour, then was quenched by a large amount of methanol. The polymer was filtered and dried by vacuum at 150 °C. As a result, 6.18g of powder polymer was obtained. The conversion was 3.40%, the activity was 0.08kg/mmol-Ti-hr. By GPC analysis, the polymer showed bimodal peaks at the molecular weight of 5000 and 562,000, respectively. The molecular weight and molecular weight distribution are shown in Table 5.

As shown in Table 5, Examples 10~11 indicated that silica calcination temperature did not affect behaviors of the silica-catalyst support in polymerization significantly. This well means that the intrinsic properties of silica surface become not important due to the existence of insulation polymer layer on the support surface. The molecular weight distribution of the product kept narrow and the molecular weight decreased with the increment of TiBA concentration.

Table 4

	Catalyst support	[Cat] mmol/L	[TiBA] mmol/L	Polym. Time min.	Yield %	Fouling %	Activity kg/mmol-Ti-h
Example 10	Silica <sup>a)</sup>	0.2	80	120	61.2	3.6	1.39
Example 11	Silica <sup>b)</sup>	0.2	80	120	60.8	4.7	1.38
Example 12	Silica <sup>c)</sup>	0.2	80	120	67.3	2.8	1.53
Example 13	Silica <sup>c)</sup>	0.2	20	60	49.9	7.8	2.27
Example 14	Silica <sup>c)</sup>	0.2	40	60	57.7	1.3	2.62
Example 15	Silica <sup>c)</sup>	0.2	60	60	51.6	2.3	2.35
Example 16	Silica <sup>c)</sup>	0.2	80	60	50.8	2.0	2.31
Comparative Example 8	SMAO (Al:4mmol)	0.2	60	120	3.40	~ 0	0.08

Notes: a) Silica calcinated at 200°C

b) Silica calcinated at 400°C

5 c) Silica calcinated at 600°C

Polymerization conditions: SM: 200ml, [MAO]/[Ti] = 100,

Polymerization temperature: 70 °C ; rpm: 400/min.

Table 5

10

	Catalyst support	[Cat] mmol/L	[TiBA] mmol/L	Polym. Time min.	Mw × 10 <sup>-3</sup>	Mw/Mn
Example 10	Silica <sup>a)</sup>	0.2	80	120	405	2.62
Example 11	Silica <sup>b)</sup>	0.2	80	120	380	3.16
Example 12	Silica <sup>c)</sup>	0.2	80	120	353	3.16
Example 13	Silica <sup>c)</sup>	0.2	20	60	624	2.39
Example 14	Silica <sup>c)</sup>	0.2	40	60	493	1.90
Example 15	Silica <sup>c)</sup>	0.2	60	60	464	2.33
Example 16	Silica <sup>c)</sup>	0.2	80	60	308	2.32
Comparative Example 8	SMAO (Al: 4mmol)	0.2	60	120	376	35.5 bimodal

Notes: a) Silica calcinated at 200°C

b) Silica calcinated at 400°C

c) Silica calcinated at 600°C

Polymerization conditions: SM: 200ml, [MAO]/[Ti] = 100,

Polymerization temperature: 70 °C ; rpm: 400/min.

### Examples 17~20

#### 5 Preparation of Silica-Supported Catalyst

10g of silica-catalyst support of which silica was calcinated at 600°C for 6 hours was suspended in 100ml toluene, 2mmol of Cp\*Ti(OCH<sub>3</sub>)<sub>3</sub> in 50ml toluene solution was added by cannula. The slurry was stirred at 70°C for 2 hours, and then, the stirrer was switched off, toluene phase became colorless. The supernatant toluene  
10 was removed by filtering and the solid was washed with toluene again at 70°C. After removal of toluene by filtering and vacuum dry, a bright-yellow finely divided powder was obtained as the silica-supported catalyst. The titanium content of the supported catalyst was calculated to be 0.2mmol/g.

#### 15 Polymerization Using Silica-Supported Catalyst

To a dried 1L-glass reactor equipped with a circulation water jacket for temperature control and an anchor-paddle impeller (made of steel), 200ml of purified styrene monomer and 3ml of triisobutyl aluminum (60mmol/L-SM) were added. The solution was stirred at 70 °C and 400 rpm for 10 minutes, and then  
20 1.41ml of 2.83M methyl aluminoxane (4 mmol) toluene solution and 0.2g silica-supported catalyst suspended in 15 ml toluene were injected. Polymerization proceeded for 1 hour, then was quenched by a large amount of methanol. The polymer was filtered and dried by vacuum at 150 °C . As a result, 90.5g of powder polymer was obtained. The conversion was 49.8% , the activity was 2.26kg/mmol-  
25 Ti-hr and the reactor fouling was 3.0wt% .

The polymer obtained was analyzed by <sup>13</sup>C NMR and DSC to be a highly syndiotactic polystyrene with the melting point of 270 °C . The weight-average molecular weight (Mw) and molecular weight distribution (Mw/Mn) were determined by GPC.

30 Examples 18-20 were carried out in the same manner as Example 17 except

that isobutyl aluminum was used at 40, 60 and 80 mmol/L in Examples 18, 19 and 20, respectively.

The polymerization conditions and resulting data were listed in Tables 6 and 7.

## 5 Comparative Example 9

The procedures in Example 10 and Example 17 were repeated except that the supported catalyst was prepared without using the SAN polymer. The supported catalyst was made by directly loading the metallocene catalyst ( $\text{Cp}^*\text{Ti}(\text{OCH}_3)_3$ ) on the MAO-treated silica surface without using the insulation polymer (SAN).

The same polymerization procedures as in Examples 17~20 were repeated except that the supported catalyst prepared above was used. As the results, no polymer was acquired, indicating decisive role of the insulation polymer (SAN) on the polymerization activity. The polymerization conditions and resulting data were listed in Tables 6 and 7.

Table 6

	Silica-supported catalyst mmol/L	[TiBA] mmol/L	Polym. time min.	Yield %	Fouling %	Activity kg/mmol-Ti-h
Example 17	0.2	20	60	35.7	2.8	1.62
Example 18	0.2	40	60	40.6	5.0	1.85
Example 19	0.2	60	60	49.8	3.0	2.26
Example 20	0.2	80	60	33.6	2.3	1.53
Comparative Example 9	0.2	60	60	0.0	---	---

Polymerization conditions: SM: 200ml,  $[\text{MAO}]/[\text{Ti}] = 100$  ( $[\text{SMAO}]/[\text{Ti}] = 100$  in Comparative Example 9), Polymerization temperature: 70 °C; rpm: 400/min.



Table 7

	Silica-supported catalyst mmol/L	[TiBA] mmol/L	Polym. Time min.	Mw $\times 10^{-3}$	Mw/Mn
Example 17	0.2	20	60	623	2.12
Example 18	0.2	40	60	586	1.94
Example 19	0.2	60	60	501	2.26
Example 20	0.2	80	60	454	2.25
Comparative Example 9	0.2	60	60		

Polymerization conditions: SM: 200ml, [MAO]/[Ti] = 100 ([SMAO]/[Ti] = 100 in Comparative Example 9), Polymerization temperature: 70°C; rpm: 400/min.

As shown in Tables 6 and 7, no activity was detected by using the supported catalyst which was made by directly loading the metallocene catalyst, (Cp\*Ti(OCH<sub>3</sub>)<sub>3</sub>), on the MAO-treated silica surface without using the insulation polymer (SAN), and there was extremely low activity when SMAO/Cp\*Ti(OCH<sub>3</sub>)<sub>3</sub> was used, in stead of SAN-insulated silica-supported catalyst

By using the polymer-insulated supported catalyst, not only productivity of syndiotactic polystyrene was remarkably improved, but also reactor fouling was significantly reduced as compared with the homogeneous catalyst when stirring-tank reactor was employed. Polymer-insulation technique of present invention endows supported catalyst with a great industrial applicability.

In the above, the present invention was described based on the preferred embodiment of the present invention, but it should be apparent to those ordinarily skilled in the art that various changes and modifications can be added without departing from the spirit and scope of the present invention. Such changes and modifications should come within the scope of the present invention.

**What is claimed is:**

1. A supported catalyst for producing a syndiotactic styrenic polymer, which comprises:

- 5 (A) a support with a high-surface area;  
(B) a polymer coated onto the support; and  
(C) a homogeneous transition metal compound as essential component;

wherein the polymer functions an insulation layer between the support and the metal compound.

10

2. The supported catalyst of claim 1 in which said polymer is harmless to catalyzation performances, interactive with the catalyst and support, and insoluble in the styrenic monomer or polymerization solvent after the catalyst is loaded.

15

3. The supported catalyst of claim 1 in which said polymer contains polar groups.

20

4. The supported catalyst of claim 1 in which said polymer is selected from the group consisting of acrylonitrile-containing polymers and copolymers, hydroxyl group-containing polymer and copolymers, acrylic and acrylate polymers and copolymers, maleic anhydride-containing copolymers and maleic anhydride modified polymers, acetate containing polymers and copolymers, polyethers, polyketones, polyamide polymer and copolymers, and polyurethanes.

25

5. The supported catalyst of claim 4 in which said acrylonitrile-containing polymer or copolymer is selected from the group consisting of polyacrylonitrile, acrylonitrile-styrene block copolymer, styrene-acrylonitrile random copolymer, acrylonitrile-butadiene-styrene resin, acrylonitrile-butadiene random copolymer, and acrylonitrile-isoprene random copolymer.

30

6. The supported catalyst of claim 5 in which said styrene-acrylonitrile random

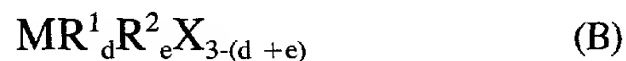
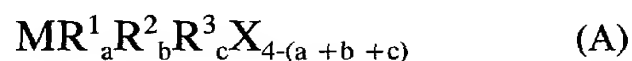
copolymer has a degree of polymerization of at least 5 and contains about 0.1 to 100 % by weight of acrylonitrile.

7. The supported catalyst of claim 1 in which said polymer is about 0.0001 to 99.999 % by weight.

8. The supported catalyst of claim 1 in which said support is an organic material selected from the group consisting of poly(styrene-co-divinylbenzene) bead, starch powder and polyolefin powder.

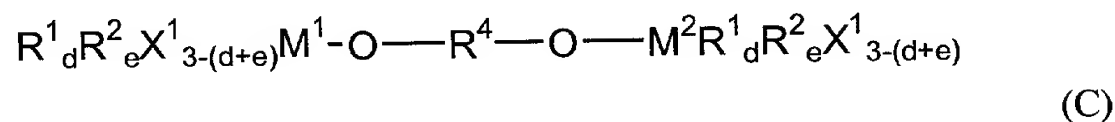
9. The supported catalyst of claim 1 in which said support is an inorganic material selected from the group consisting of silica gel, alumina, silica-alumina gel, zeolite, mica powder, clays, molecular sieves, metal oxide compounds, metal halogenides, metal carbonates and metal powder.

10. The supported catalyst of claim 1 in which said homogeneous transition metal compound is a metal compound of Group IVB represented by the following formula (A) or (B):

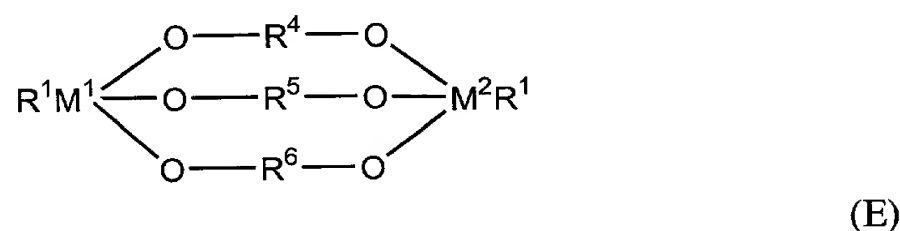
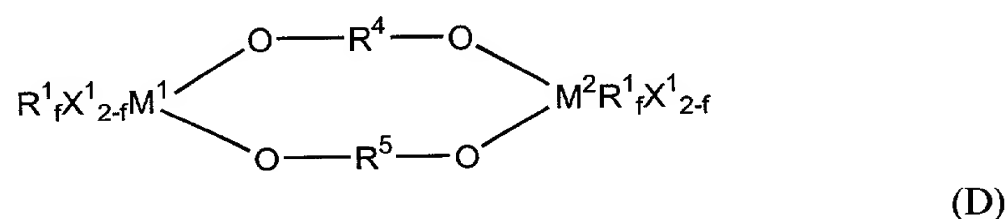


where M is an atom of Group IVB,  $R^1$ ,  $R^2$  and  $R^3$  are a hydrogen atom, an alkyl group having 1 to 20 carbon atoms, an alkoxy group having 1 to 20 carbon atoms, an aryl group having 6 to 20 carbon atoms, an alkylaryl group having 6 to 20 carbon atoms, an arylalkyl group having 6 to 20 carbon atoms, an aryloxy group having 1 to 20 carbon atoms, a cyclopentadienyl group, a substituted cyclopentadienyl group or an indenyl group, X is a halogen atom, a, b and c are an integer of 0 to 4, and d and e are an integer of 0 to 3.

11. The supported catalyst of claim 1 in which said homogeneous transition metal compound is a binuclear catalyst represented by the following formula (C), (D) or (E):

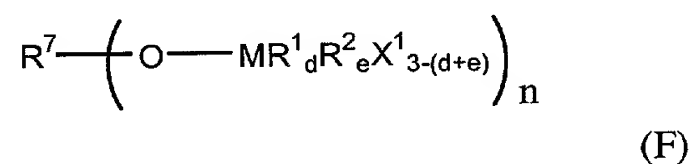


5



10 where  $M^1$  and  $M^2$  are an atom of Group IVB,  $R^1$ ,  $R^2$ ,  $R^4$ ,  $R^5$  and  $R^6$  are an alkyl group having 1 to 20 carbon atoms, an aryl group having 6 to 20 carbon atoms, an alkylaryl group having 6 to 20 carbon atoms, an arylalkyl group having 6 to 20 carbon atoms, a cyclopentadienyl group, a substituted cyclopentadienyl group or an indenyl group, X is a halogen atom, d and e are an integer of 0 to 3, and f is an  
15 integer of 0 to 2.

12. The supported catalyst of claim 1 in which said homogeneous transition metal compound is a multiple-nuclear catalyst represented by the formula (F):



20

where M is an atom of Group IVB, R<sup>1</sup> and R<sup>2</sup> are an alkyl group having 1 to 20 carbon atoms, an aryl group having 6 to 20 carbon atoms, an alkylaryl group having 6 to 20 carbon atoms, an arylalkyl group having 6 to 20 carbon atoms, a cyclopentadienyl group, a substituted cyclopentadienyl group or an indenyl group, R<sup>7</sup> is an alkyl group having 1 to 20 carbon atoms, an aryl group having 6 to 20 carbon atoms, an alkylaryl group having 6 to 20 carbon atoms, an arylalkyl group having 6 to 20 carbon atoms, or a polymer having a polymerization degree of 5 to 10000, X is a halogen atom, d and e are an integer of 0 to 3, and n is an integer of 3 to 1000.

13. The supported catalyst of claim 1 in which said polymer is about 0.0001 to 30 % by weight.

14. The supported catalyst of claim 1 further comprising (D) alkyl aluminoxane and/or (E) alkyl aluminum compound.

15. A method of preparing a supported catalyst for producing a syndiotactic styrenic polymer, which comprises:

providing a support precursor by drying the slurry of a support with a high-surface area, a polymer to be coated onto the support, and a solvent; and adding a homogeneous transition metal compound and a solvent to the support precursor.

16. The method of preparing a supported catalyst according to claim 15, which further comprises:

adding alkyl aluminoxane and/or alkyl aluminum compound to the slurry prior to the second step.

17. A method of producing a syndiotactic styrenic polymer, which comprises

using a supported catalyst comprising a support with a high-surface area, a polymer

coated onto the support, and a homogeneous transition metal compound as essential component, the polymer functions an insulation layer between the support and the metal compound.

- 5 18. A method of producing a syndiotactic polymer, which comprises using a supported catalyst comprising a support with a high-surface area, a polymer coated onto the support, and a homogeneous transition metal compound as essential component, the polymer functions an insulation layer between the support and the metal compound.

10

19. The method of producing a syndiotactic polymer according to claim 18 wherein said syndiotactic polymer is styrenic polymer, olefin polymer or styrene-olefin copolymer.

15

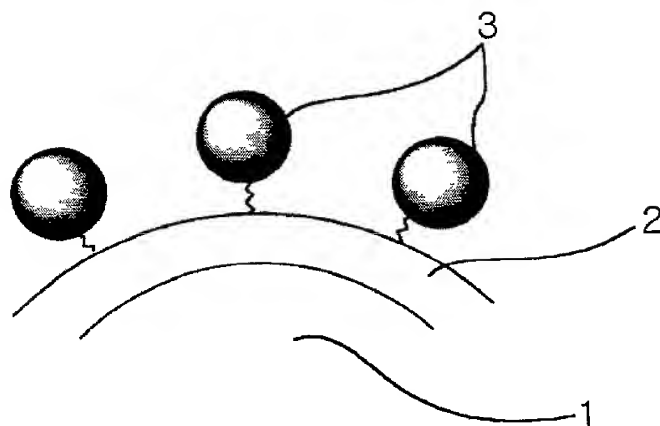
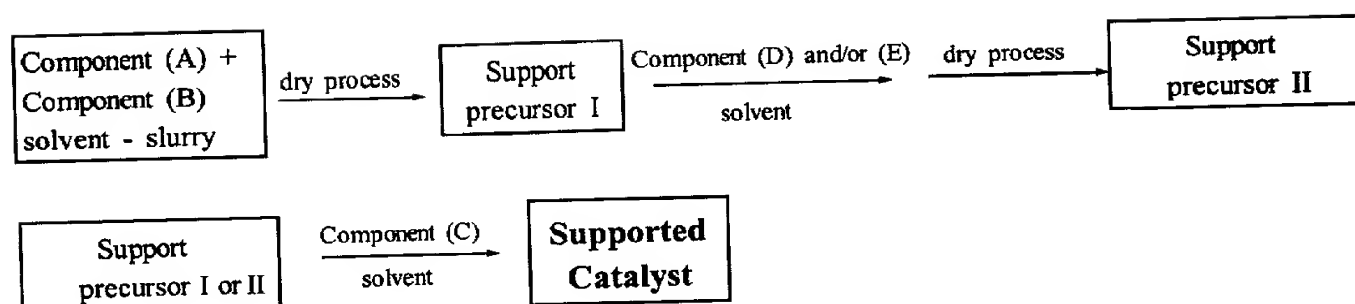
20

25

30

### Abstract of the Disclosure

The supported catalyst according to the present invention comprises (A) a support of organic or inorganic powder with a high-surface area, (B) a polymer coated onto the support and (C) a homogeneous transition metal compound as essential component, the polymer functioning an insulation layer between the support and the metal compound. The supported catalyst can contain optionally (D) alkyl aluminoxane and/or (E) alkyl aluminum compound. By using the supported catalyst provided by the present invention, the productivity of styrenic polymer is much increased and the reactor fouling was significantly reduced. The supported catalyst can be used in combination with a cocatalyst, preferably an alkyl aluminoxane. The styrenic polymer powder such produced by the present invention has good flow-ability and good morphology demonstrating a great deal of industrial applicability.

**Fig. 1****Fig. 2**



DOCKET NO.

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In Re Application of:

Xuequan ZHANG; Sung-Cheol YOON; Jae-Gon  
LIM and Young-Sub LEE

Group Art Unit: Not yet  
assigned

Examiner: Not yet assigned

For: SUPPORTED CATALYST FOR  
PRODUCING SYNDIOTACTIC  
STYRENE POLYMER WITH HIGH  
PRODUCTIVITY AND REDUCED  
REACTOR FOULING

DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name; and

I believe that I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a

☒ Utility Patent ☐ Design Patent

is sought on the invention, whose title appears above, the specification of which:

- ☒ is attached hereto.  
☐ was filed on \_\_\_\_\_ as Serial No. \_\_\_\_\_.  
☐ said application having been amended on \_\_\_\_\_.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the U.S. Patent and Trademark Office all information known to be material to the patentability of this application in accordance with 37 CFR § 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. § 119(a-d) of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of

DOCKET NO.

- 2 -

PATENT

any application on which priority is claimed:

Priority Claimed (If X'd)	Country	Serial Number	Date Filed
<input checked="" type="checkbox"/>	Korean	2000-45602	August 7, 2000
<input type="checkbox"/>			
<input type="checkbox"/>			
<input type="checkbox"/>			

I hereby claim the benefit under 35 U.S.C. § 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of 35 U.S.C. § 112, I acknowledge the duty to disclose to the U.S. Patent and Trademark Office all information known to be material to patentability as defined in 37 CFR § 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

Serial Number	Date Filed	Patented/Pending/Abandoned

I hereby claim the benefit under 35 U.S.C. § 119(e) of any United States provisional application(s) listed below:

Serial Number	Date Filed

I hereby appoint the following persons of the firm of WOODCOCK WASHBURN KURTZ MACKIEWICZ & NORRIS LLP, One Liberty Place - 46th Floor, Philadelphia, Pennsylvania 19103 as attorney(s) and/or agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:


Gary H. LevinReg. No. 28,734

Reg. No. \_\_\_\_\_

Address all telephone calls and correspondence to the first-listed attorney of record at:

WOODCOCK WASHBURN KURTZ  
MACKIEWICZ & NORRIS LLP  
One Liberty Place - 46th Floor  
Philadelphia PA 19103  
Telephone No.: (215) 568-3100  
Facsimile No.: (215) 568-3439

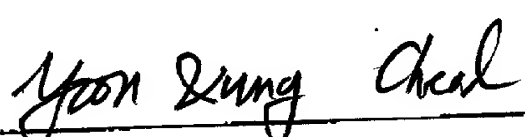
I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

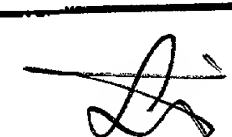
Name	Xuequan ZHANG	
Mailing Address	Sejong Apt. 104-302, Jeonmin-dong Yuseong-gu, Taegeon 305-390, Korea	Signature
		Date of Signature: <u>8/30, 2000</u>
City/State of Actual Residence	Taegeon 305-390, Korea	Citizenship: <u>Chinese</u>

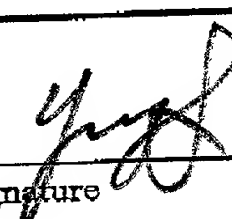
DOCKET NO.

- 4 -

PATENT

Name	Sung-Cheol YOON	 Signature	
Mailing Address	113-20, Sangbong-2dong 12/2 Chungnang-gu, Seoul 131-222, Korea		Date of Signature: <u>2000. 8. 30.</u>
City/State of Actual Residence	Seoul 131-222, Korea		Citizenship: <u>Korean</u>

Name	Jae-Gon LIM	 Signature	
Mailing Address	Sejong Apt. 101-708, Jeonmin-dong Yuseong-gu, Taegeon 305-390, Korea		Date of Signature: <u>2000. 8. 30</u>
City/State of Actual Residence	Taegeon 305-390, Korea		Citizenship: <u>Korean</u>

Name	Young-Sub LEE	 Signature	
Mailing Address	Sejong Apt. 107-806, Jeonmin-dong Yuseong-gu, Taegeon 305-390, Korea		Date of Signature: <u>2000. 8. 30.</u>
City/State of Actual Residence	Taegeon 305-390, Korea		Citizenship: <u>Korean</u>